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VOL. 29 No. 2

BULLETIN

OF THE

TORREY BOTANICAL CLUB

FEBRUARY 1902

On the Teaching of Vegetable Pathology*

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It is generally recognized at the present time that the scientific man has not completed his labors when he has determined to his own satisfaction what the solution of any particular phenomenon in which he is interested, may be. The time was when it was considered sufficient for him to publish his results in an abstract form where a few of his colleagues might read and understand them. To-day we regard it as one of the duties and privileges to make accessible to those not immediately engaged in one particular line of research, the results of the work in the laboratory and the field.

I take it, that as many of us are engaged in teaching the various branches of botanical science to students, it may be a legitimate question to discuss before this Society what we are doing with our college classes, and how we can best accomplish our object. It is my purpose to-day to bring before you for discussion, some thoughts as to how we can best train those who intend to devote themselves to the study of vegetable pathology.

Of the several lines of botanical research, that which is generally termed vegetable pathology is beginning to claim more general attention at this time. Courses are being offered in some of our colleges and universities, which deal with diseases of plants, although for the most part these are mere adjuncts of courses in

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* A paper read before the Society of Plant Morphology and Physiology, New York. 31 December 1901.

[Issued 25 February]

cryptogams. The time is not far distant, however, when vegetable pathology as a separate branch of botanical science will assert itself and claim recognition independent of the other branches of this science, and when we will have professors of pathology, who will devote their time and attention to this subject alone. At the present time the demand for properly trained men to take up work in the study of plant diseases is increasing every year, and with the rapid development of scientific agriculture, economic questions involving the study of plant pathology are becoming more numerous, and demand more urgent solution. The economic side alone will be sufficient to bring about radical changes in the present condition of this science in our institutions of higher education.

By vegetable pathology I mean to imply the study of plant diseases in its widest sense. It is perhaps not easy to define disease accurately, but for our present purposes, it will be sufficient to speak of disease as abnormal physiology, or, as it has been termed by Marshall-Ward, "a variation of functions in directions which threaten the life of the plant."

It is essential that we understand at the outset that we are dealing with a living plant and the reactions which its parts show toward environmental conditions. What we are studying are diseased *plants*, as distinguished from disease-causing factors. This is to be the fundamental conception of this paper. We have been studying mildews and rusts long enough, and in so doing made ourselves believe we were studying pathology, and it is high time that it were realized that the patient is after all more important than the disease-bringing factor. Assuming that all are agreed upon this point, and taking this as a starting-point, let us inquire how we can go about to teach this conception of pathology. It is evident that a knowledge of the morphology of fungi will not be sufficient, and that a very different method must be adopted from the one in vogue in many of our colleges at this time.

In the first place let me say that we can learn much from the kindred science of animal pathology. The study of this subject is generally divided into three groups: (1) Diagnosis, (2) Etiology, (3) Therapeutics. In all cases the living object is first consulted, then the causal factors, and lastly the remedy. Applying this to plants we find that the symptoms of disease are on the whole not as sharply defined as in animals. This is due in part to the lower degree of organization of the plant, and also to the fact that a good many disturbing factors give rise to similar symptoms. We can, however, analyze the symptoms with far greater ease than is possible in animals. Environmental conditions can be controlled, and by a method of elimination the disturbing factor can be determined positively. The study of the disturbing factor, whether it be environmental or due to living organisms, can also be carried on with more success with plants than with animals. In other words, we can make the study of pathology one involving experimentation with living plants.

This brings me to speak of the things necessary for a course in pathology conforming to the above. In the first place one or more greenhouses are absolutely essential, together with a liberal supply of living plants. If carried on in the spring and summer the greenhouse is not so essential. Access to greenhouses where different kind of plants are growing is also desirable. In St. Louis we have established a vegetable clinic, where patients are received and observed. The greenhouse, or houses, ought to be divided into numerous compartments, each completely sealed from the others preferably, so as to prevent the spreading of fungus spores. I wish to call attention to a series of houses built by Dr. von Tubeuf at Dahrlem, near Berlin, which are ideally arranged for work in experimental pathology. The number and kind of plants needed depend largely upon the amount of work which one contemplates doing. Wheat, corn, oats, cabbages, roses, lettuce, cotton, and other common plants easily obtained, will be found ample in most cases. Living material of fungi, obtained from diseased plants, or kept as cultures, will also be essential.

Before proceeding further a word ought to be said about the preparation which we ought to expect of students engaging in this study. As pathology is essentially abnormal physiology, a thorough knowledge of plant physiology should be required. This is so obvious that it is hardly necessary to urge it, and yet it is a curious fact that, so far as I have been able to determine, this is demanded, and that not very decidedly, in only one institution. Too much stress cannot be laid on this requirement, and under no consideration ought pathology, as we now understand it, to be studied without physiology as a basis. I can leave this part by simply referring to the absurdity of a medical student studying human pathology without understanding the circulation of the blood. Next in importance comes a knowledge of chemistry, and preferably at least a year of organic chemistry, and a knowledge of physics. Physiological problems are becoming more and more physico-chemical problems, and a thorough understanding of these sciences is absolutely essential. A good reading knowledge of modern languages, an understanding of the morphology of higher plants, and if possible of fungi and bacteria, together with an ability to grow fungi and bacteria may complete the list. This preparation would mean that a course in pathology could not be begun until the senior year or thereafter.

Coming now to the main subject as to what we are to teach, I would simply offer a few broad suggestions. It really does not make much difference as to how the subject is divided, so long as some of the fundamental conceptions of disease are included. The amount of work which one will be able to accomplish will depend upon the individual. I believe firmly that we ought to train a student so that he can think and work for himself, and that this should be kept uppermost at all times. It is impossible in the course of a year to study all diseases of plants, and granting that this is true, we must select certain fundamental facts to impress upon the student, allowing him to work out many others for himself later on. Such fundamental facts are the cause of disease, the symptoms of disease, the way in which diseases spread, the prevention of disease, and the nature of disease. In his treatise on the Diseases of Plants recently issued, Professor Marshall Ward has discussed the topics just mentioned in a suggestive manner, and in a way not presented before.

Taking it for granted that the student is familiar with the normal physiological behavior of a cell and cell-groups, one may begin the study of disease by noting the change in single cells or cell-groups under abnormal conditions, and the reactions which are induced by these conditions. The study of wounds offers a very fruitful field for the beginner, for we find in a wound one set of changes which cells undergo when diseased. The irritable nature of the cell which enables it to form a protection against the air, and later on the protecting cork layer and the callus is fully brought out in that connection. I have found succulent stems and leaves very good for the study of wounds, particularly the leaves of the cauliflower. In this connection the wounds caused by insects can be studied, and the peculiar response which the living tissue makes to the disturbing cause. Plant lice abound everywhere, and so do gall flies, so that there is never any trouble in getting living material for study. Following this one may observe the influence of living organisms in cells, for instance, the manner in which the various Chytridiaceae influence the leaf tissue. From these one may continue with the more complex reactions of fungi like *Albugo*, *Exoascus*, and *Gymnosporangium*. With all of these it is possible to keep the fungus, and the leaves attacked, under constant observation. With some it is not easy, for instance the *Exoascus* and *Gymnosporangium*; these had best be observed out-of-doors in the spring; with a little judicious planning it is feasible to postpone the study of these complex reactions until the latter part of the course. *Albugo* and *Synchytrium* can be grown on plants in greenhouses. Very different from the influence exerted by these fungi is that exerted by others like *Botrytis*, the Uredineae, and the Peronosporeae. It will be sufficient for me to refer to this simply, as the reasons why these should be included are obvious enough.

If time permits, the changes in cell-groups near wounds and spots attacked by fungi can be studied, *i. e.*, the formation of wound gums, the increased evolution of heat and the rapid transformation of plastic food bodies, the accumulation of starch, etc.

A second line of work grows out of the question as to what causes disease. This question involves most of the others mentioned above, and can be made the starting point for all. Using the convenient division of disease caused by the action of either environmental factors of living organisms, one can begin by experimenting with unfavorable environmental conditions. In doing so it is of course hardly necessary to say that great care must be used in devising experiments which will give definite results. To illustrate: if the influence of excessive heat is to be studied, one must be sure that the light, moisture and gaseous conditions are the same. As a rule it will prove most satisfactory to work with those factors which can be most readily handled, for it is after all, as has been said, the method of study that we are after, rather than a long series of facts. This part of the work can of course be carried on hand-in-hand with that part first suggested, for it is not possible to separate cause and effect.

Coming next to the influence of living organisms, a large field is opened with any number of possible lines of work. One of the first points to be demonstrated is that fungi or bacteria are the causes of disease. For this purpose it is well to select a fungus which grows readily and reproduces rapidly. There are a number of these. This fall we found *Erysiphe graminis* growing on wheat, a most interesting fungus to work with. I can perhaps make my meaning clearest by relating briefly what we did. A preliminary discussion brought out a number of questions which we desired to answer, such as : (1) Does this fungus produce the disease of wheat which it was found connected with, *i. e.*, will it make perfectly healthy plants diseased ? (2) How does it do so; in other words, what is the relation of the fungus and the wheat leaf ? (3) Will the spores of the fungus produce the disease in other plants besides the wheat plant, for instance oats, rye, wheat, *Poa*, corn, roses, etc. (4) Is there any connection between the ease with which this fungus attacks the wheat, and the condition of the plant to be infected ? (5) What factors favor development of the fungus ? Will the fungus grow on dead leaves ? (6) How does the spore get from plant to plant ? (7) What are the factors which determine germination of the spores ?

Each student was instructed to find a method for answering these questions, and such others as arose, and as a result we had a series of experiments started, which were watched with the utmost interest. The questions dealt with broad subjects applicable to most other fungi or disease-causing factors. The results showed that the fungus does produce the disease, and thereby answered one of the most important questions. To the average mortal "seein' is believin'," and when a student actually sees himself producing the disease in question, as he thinks, the impression gained is that of the original investigator, and is apt to be remembered. The results brought into discussion the problem of susceptibility, both of plant races and individuals ; it was found that of all the plants the wheat alone was attacked, and again that the stronger plants were less liable to attack. Again it was found that crowding helped the fungus, that moisture and warmth had the same effect, and that the spores could germinate in a drop of water. We spent a long time studying *Erysiphe graminis*, but I believe that the results amply warranted our doing so.

One might have used other fungi, for instance the clubroot of the cabbage, the cotton wilt, and others, bearing in mind that rapid growth is desirable, for when you have to wait six months or more the interest is liable to wane.

Having carried on one series such as the one described, it may be well to continue with as many more as one may have time for. Where live material of the bacterial diseases can be obtained, those will probably offer as satisfactory objects for study as could be wished for. The effect which bacteria produce on the plant is usually noticeable after brief periods. Then again pure cultures can be made easily, and these can be subjected to various conditions, to show whether vigor of the parasite has anything to do with the virulency of the disease. The rusts can be used to some extent, particularly after several years, when one has succeeded in establishing barberry plants with aecidia. The species of *Melampsora* and *Puccinia* furnish useful material.

The smuts are very instructive. We have one section of our greenhouse devoted to these, using several grains. These are covered with spores before planting and after several months the new spore crop is obtained. We have not yet tried any of the anthracnoses, probably because of the lack of living material, but they ought to be easy to handle, as pure cultures can so readily be made and kept. One might go on at length with this phase of the study. This is hardly necessary now, for to the live teacher new points of view will present themselves from time to time.

A word ought to be said about insects here, for they destroy plants as much as fungi do. The entomologist has reigned supreme in this field hitherto, probably for the same reason that the systematic mycologist has had charge of the fungus side. The biting insects which injure plants by making wounds have little interest for the pathologist aside from the wounds made. Those insects which form galls, which mine in leaves and stems, or under the bark of trees, have a decided interest for him, and ought to be alluded to at least in any course of vegetable pathology.

A third phase which I wish to touch upon briefly deals with the influence of environment on the disease-causing factors, particularly the fungi. Many spores of fungi must undergo resting periods of various lengths of time before germinating; others do not ripen until late in the winter. Sclerotia must undergo freezing or a resting period. I believe truly that there are many of us that know positively that the ascospores of *Microsphaera* germinate sometimes and produce patches of mycelium, and that the sclerotia of *Claviceps* form perithecia bearing heads, but how many of us have ever seen these spores germinating, or tested the length of time necessary to do so? We have built a "resting frame" so-called for our fungus friends in the Missouri Botanical Garden, where they lie under leaves, and are disturbed every once in a while, and put under conditions where they might change, side by side with spores or sclerotia kept indoors all the time. Sometimes our spores germinate and sometimes they never do. But even then the student learns the lesson that the spores of fungi have adapted themselves to the peculiar conditions of environment, and will respond only when these are exactly right. Under proper conditions most spores will germinate, and it is a far more instructive lesson to have them do so after repeated failure than to give up the first time. I have always remembered the sad face and drawl of the man in my class at college who said that it was all very nice to study the sections of cluster cups and see mounts of germinating teleutospores and sporidia, but he didn't think they ever did those things outside, if so, why didn't we ever see them.

Therapy, or healing, forms a small part of our study, for with plants the maxim that prevention is better than cure must always hold true. Spraying and other fungicidal methods may properly be experimented with on a small scale, but only with infected plants. With smuts the various seed treatments can be carried out without much trouble, at the same time that smut-infected seeds are planted.

Summing up briefly, I would emphasize the fact that in all the phases of this study the living plant must be kept in the foreground. It goes without saying that the division suggested above cannot be rigidly maintained, nor is it desirable. The various factors work too closely one with or against the other, but with care, each can be emphasized at the proper time. The theoretical considerations of immunity, the symptoms of disease, the spreading and the nature of disease, must go hand-in-hand with the experimental work, but should at all times be subordinated to it. Questions such as that belong to the end of a course, after the student has thoroughly grasped the meaning of the complex interrelation of plants to each other and their surroundings. Personal acquaintance with one or more diseases, and a careful analysis of each, will lead to a broader conception of disease by itself, and will make a more lasting impression on the student when he must puzzle over these questions on his own account. Nowhere is too much teaching to be deplored more than in experimental work of the kind mentioned above.